Ozone Transport to the Los Angeles Basin

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Goal:

“What are the sources and physical mechanisms that contribute to high ozone concentrations aloft that have been observed in Central and Southern California?”

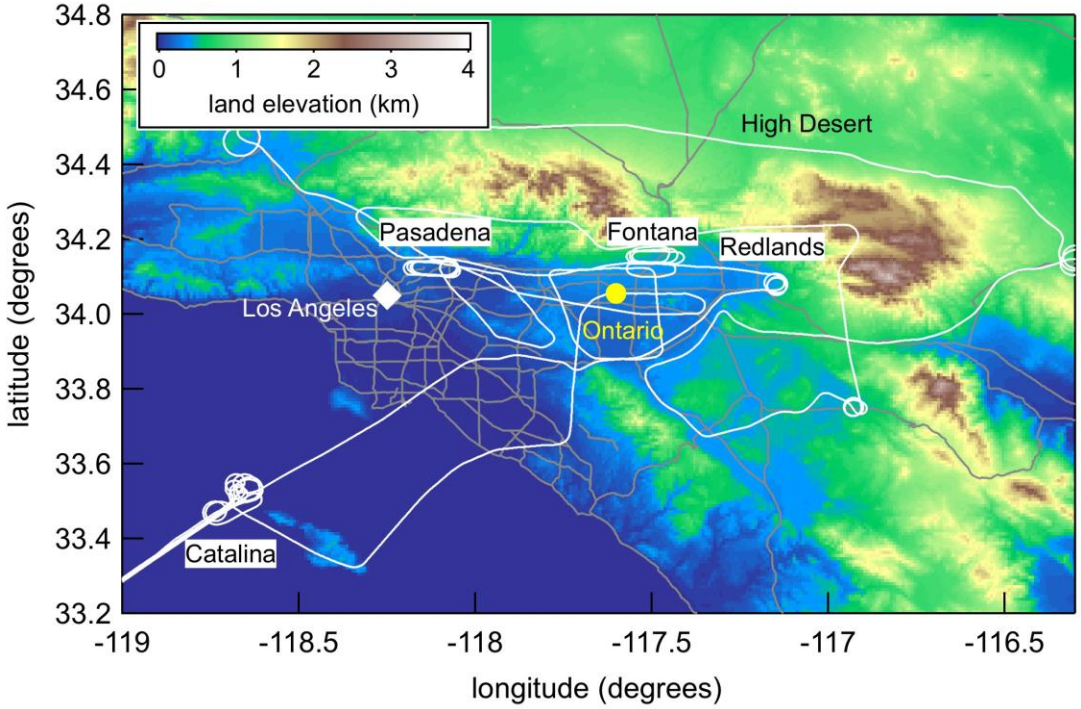
Approach:

I. Large ozone concentrations in the lower free troposphere (1-4 km) during CalNex
II. Show that different sources have distinguishing air mass chemical composition
III. Identify ozone sources and transport over the LA Basin according to air mass chemical composition
IV. Demonstrate that ozone aloft affects surface concentrations

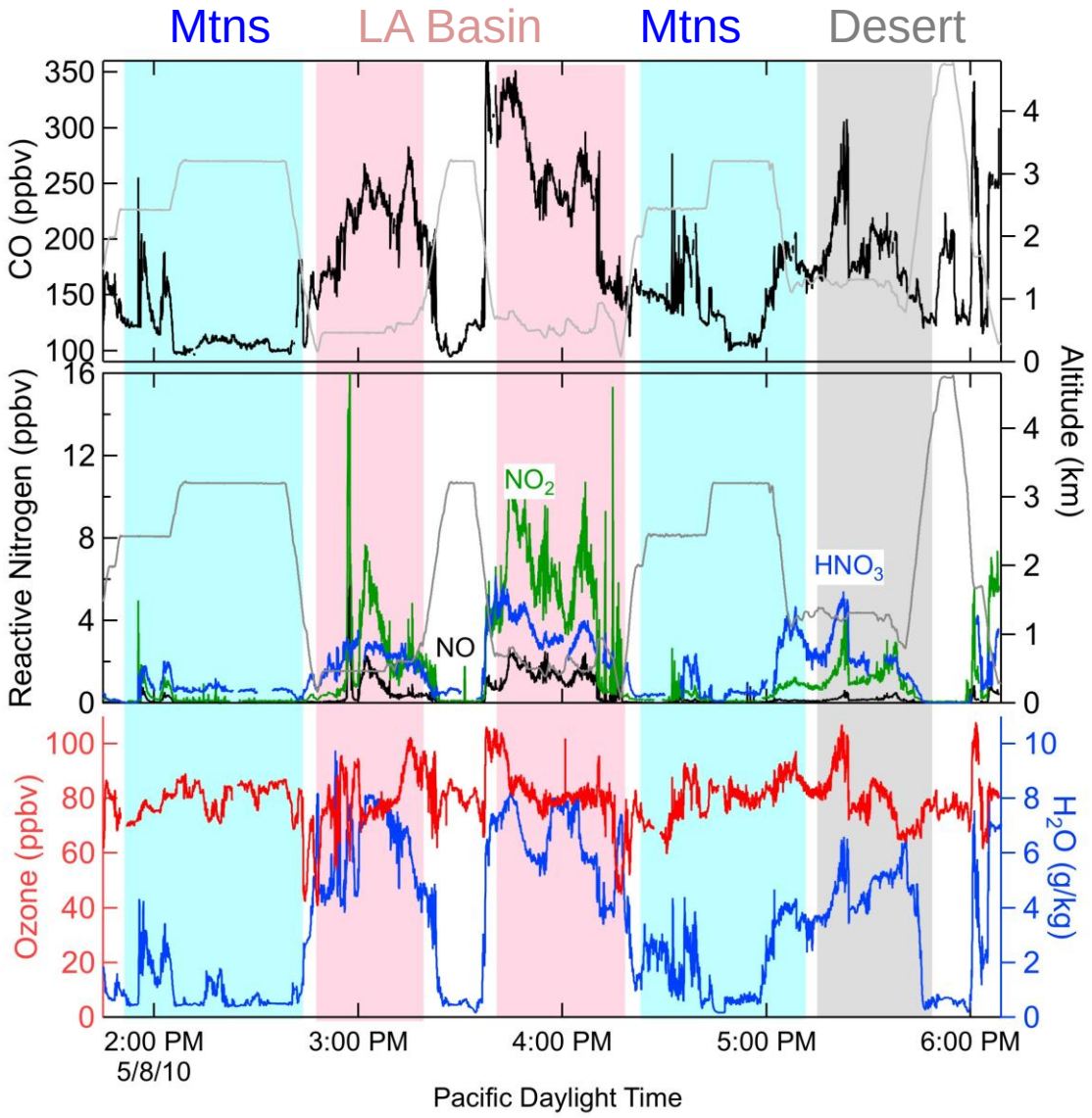
Experiment:

- NOAA WP-3 aircraft flights over California in May and June 2010
- Fast, in-situ measurements of ozone, ozone precursors, and tracers
- 7 daytime flights focused on LA Basin: May 4,8,14,16,19,21 and June 20, 2010
- Many vertical profiles between 0.2−4 km altitude

Typical Flight Track over LA Basin



Aircraft Measurements

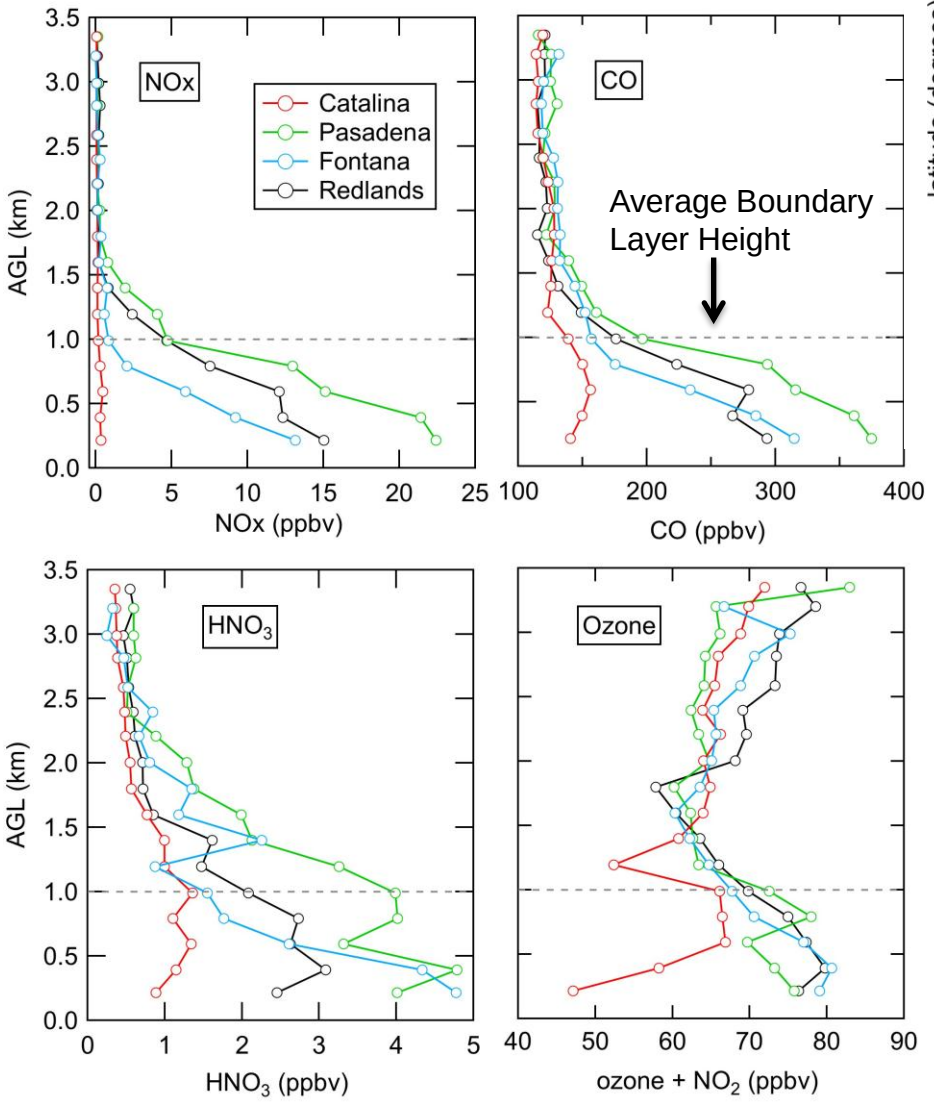


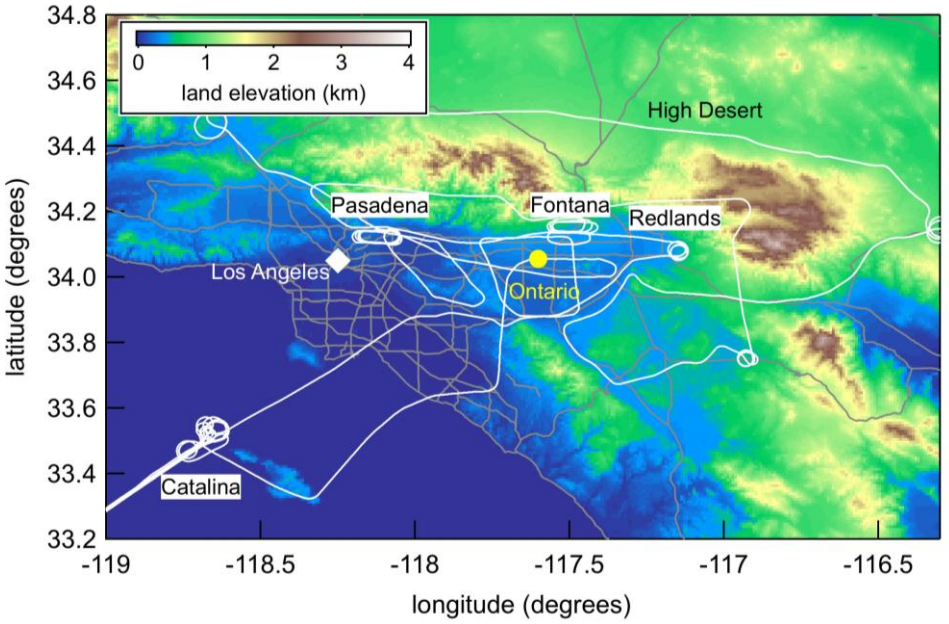
Mixing Ratios (ppbv)

	LA Basin	High Desert	Mtns
CO	300	200	100
NOx	10	2	0.1
HNO_3	6	4	1
O_3	**80**	**80**	**80**

- Ozone increased aloft (and **everywhere**)

Trace Gas Concentrations from 32 vertical profiles on 6 flights





- Composition similar at all locations from 1- 4 km (lower free troposphere)
- In the boundary layer, concentrations largest closest to sources
- Ozone increased in the lower free troposphere

Chemical composition identifies ozone sources and transport

Possible sources for air over the Los Angeles Basin:

- Marine
- Aged regional emissions
- Stratosphere
- Asia
- Upper troposphere

Use gas phase measurements to distinguish ozone sources:

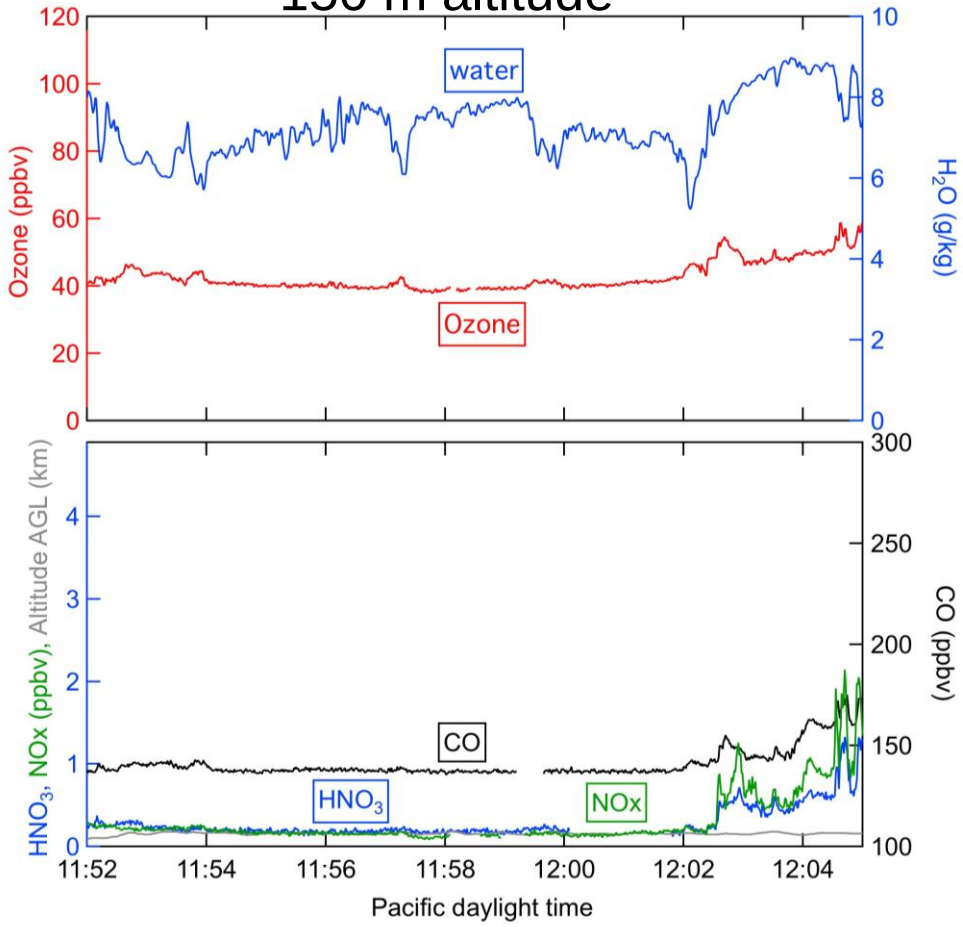
- Water
- CO
- Reactive Nitrogen (HNO_3, NOx, PAN)

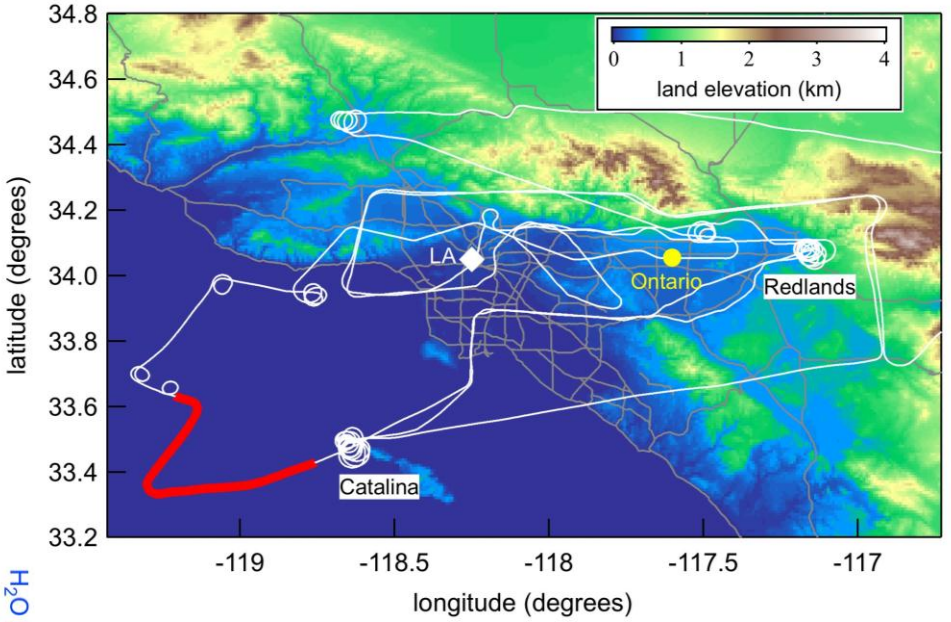
Next 4 slides: Show that each source has a distinct chemical signature

Chemical Composition

Marine

Over Pacific Ocean, May 8
150 m altitude



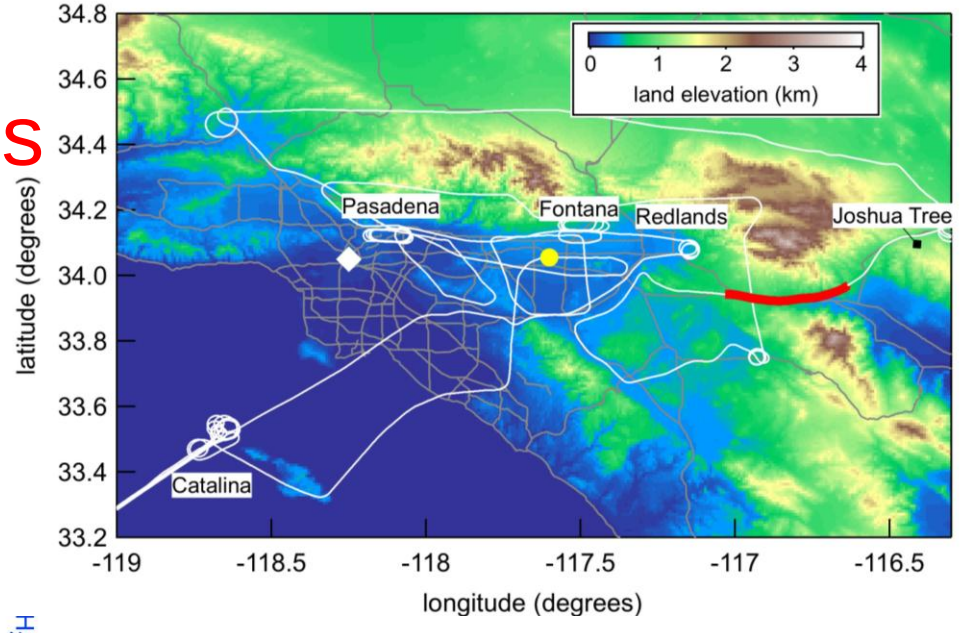


Increased Concentrations:
water

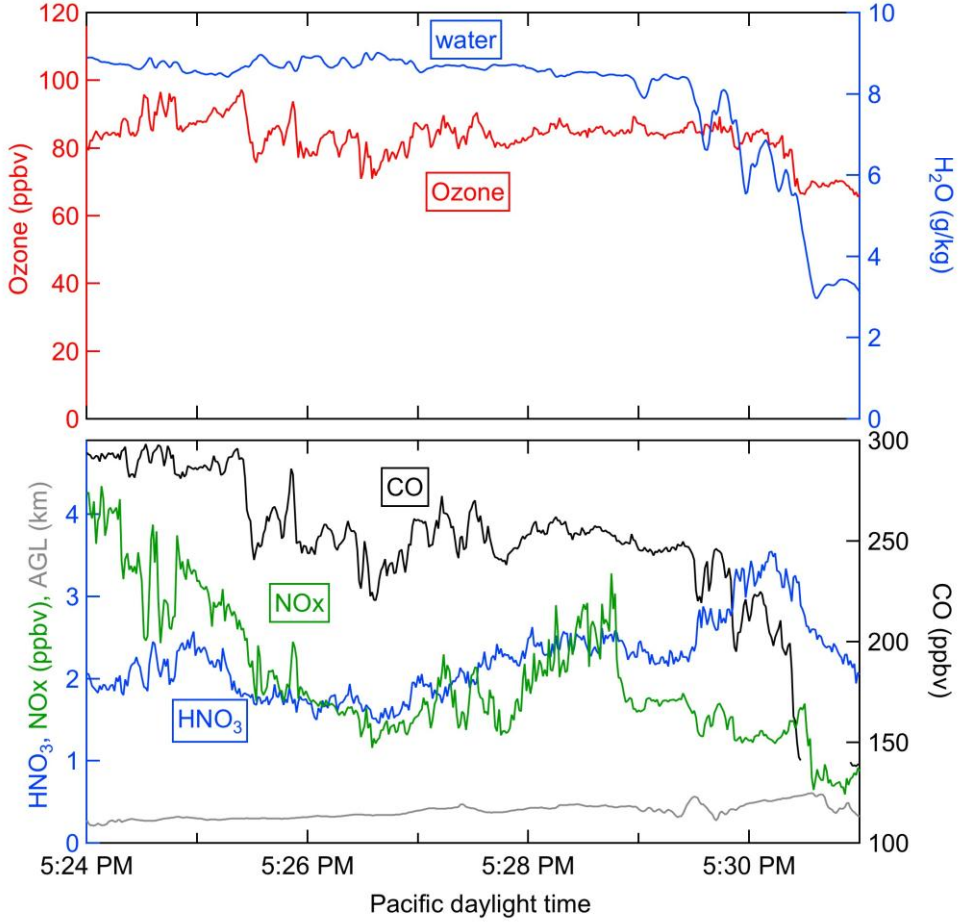
Decreased Concentrations:
Ozone, CO, HNO_3, NOx

Chemical Composition

Aged Regional Emissions



Banning Pass, May 16
300-600 m AGL



Increased Concentrations:

water

Ozone and CO

(correlated)

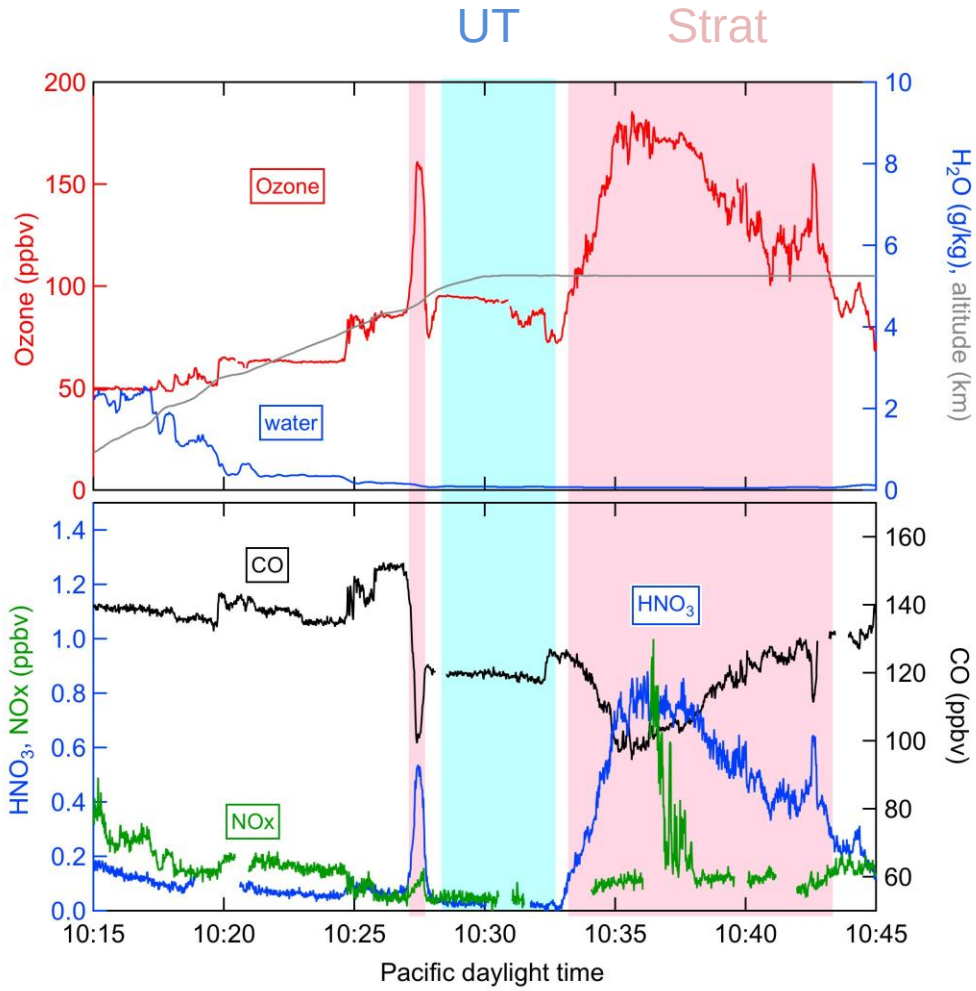
Reactive Nitrogen

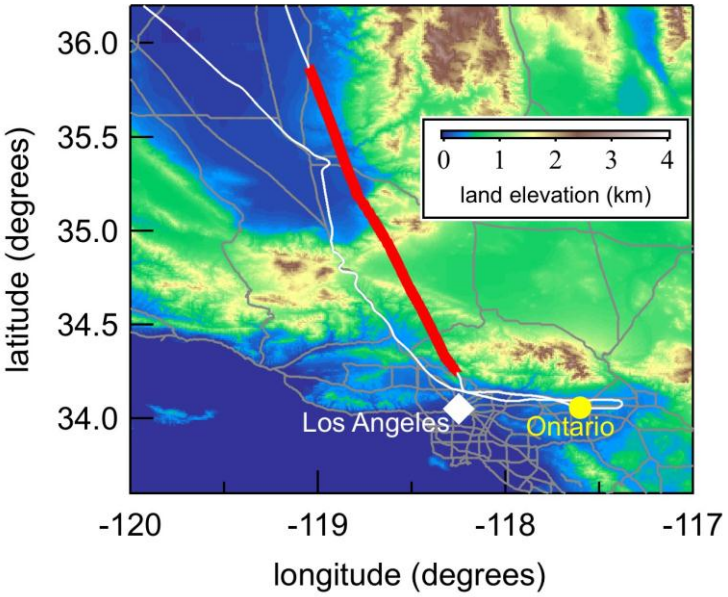
(partitions toward HNO_3)

Chemical Composition

Stratosphere/ Upper Troposphere

Over Central Valley, May 11





Stratosphere:

Increased Concentrations:

Ozone and HNO_3 *(correlated)*

Decreased Concentrations:

CO, water

Upper Troposphere:

Increased Concentrations:

Ozone

Decreased Concentrations:

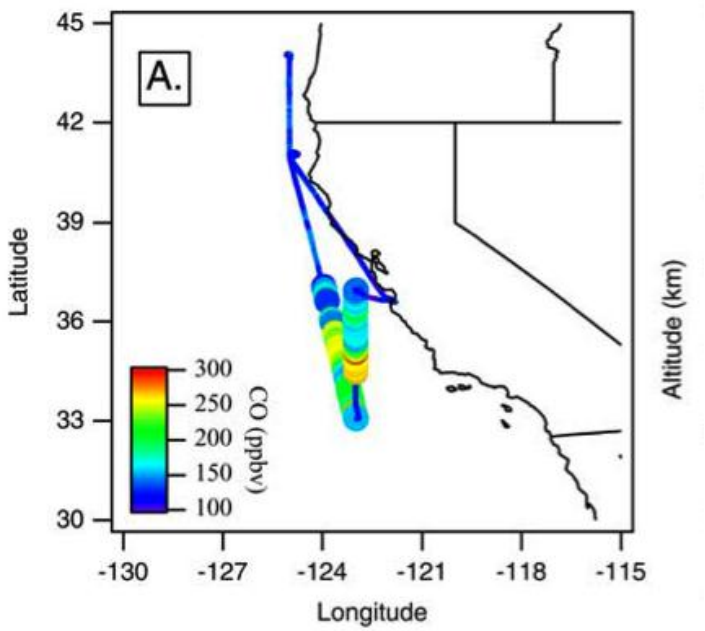
CO, water, HNO_3

Chemical Composition

Transported Plumes from Asia

Over Pacific Ocean, May 2002

Nowak, J. B., et al. (2004), Gas-phase chemical characteristics of Asian emission plumes observed during ITCT 2K2 over the eastern North Pacific Ocean, J. Geophys. Res., 109, D23S19, doi:10.1029/2003JD004488.



Increased Concentrations:

CO, PAN

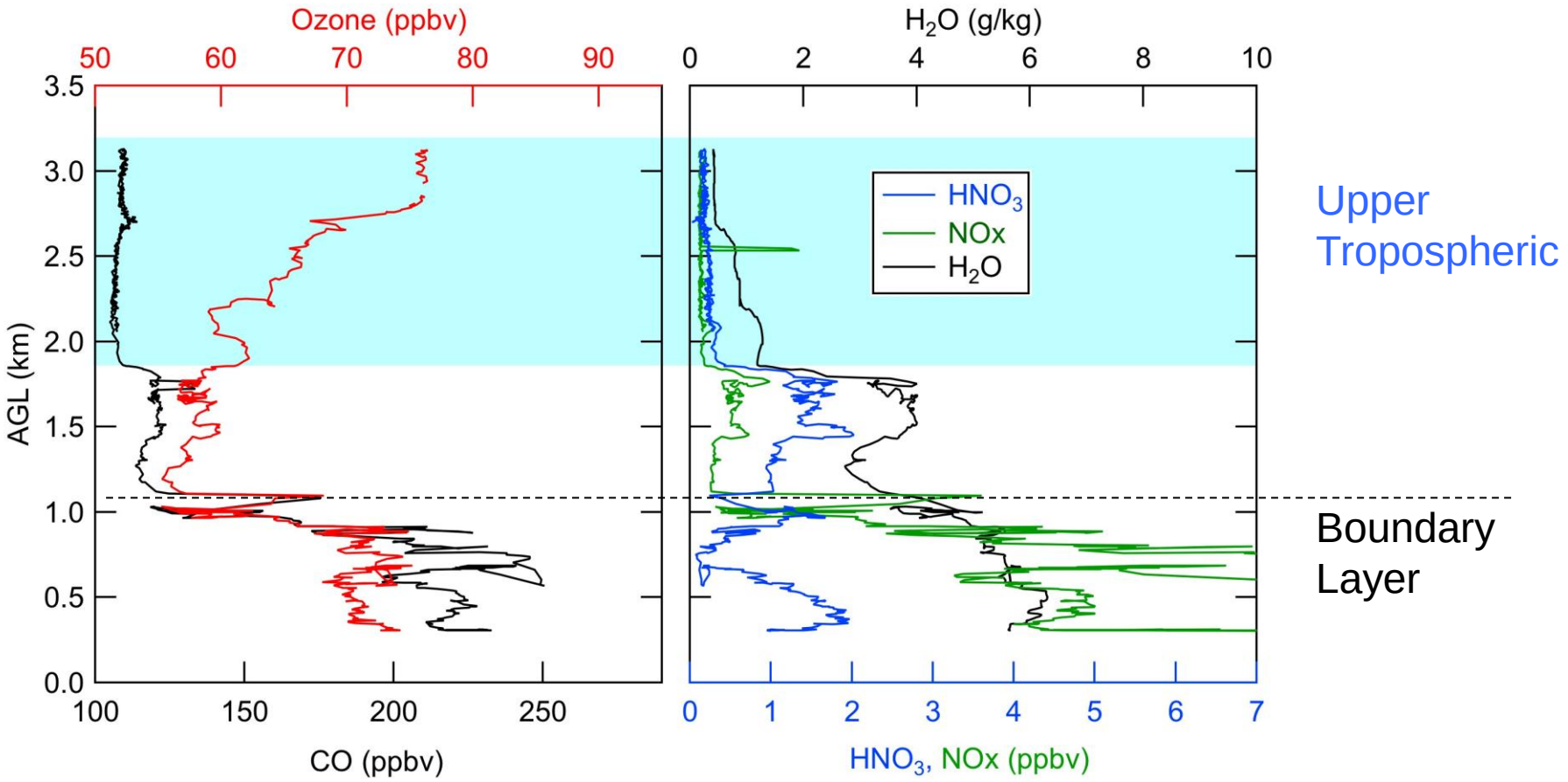
Decreased Concentrations:

HNO_3

Next 3 slides: Identify air masses over LA Basin during Calnex by their chemical composition

Ozone in the lower free troposphere over the LA Basin

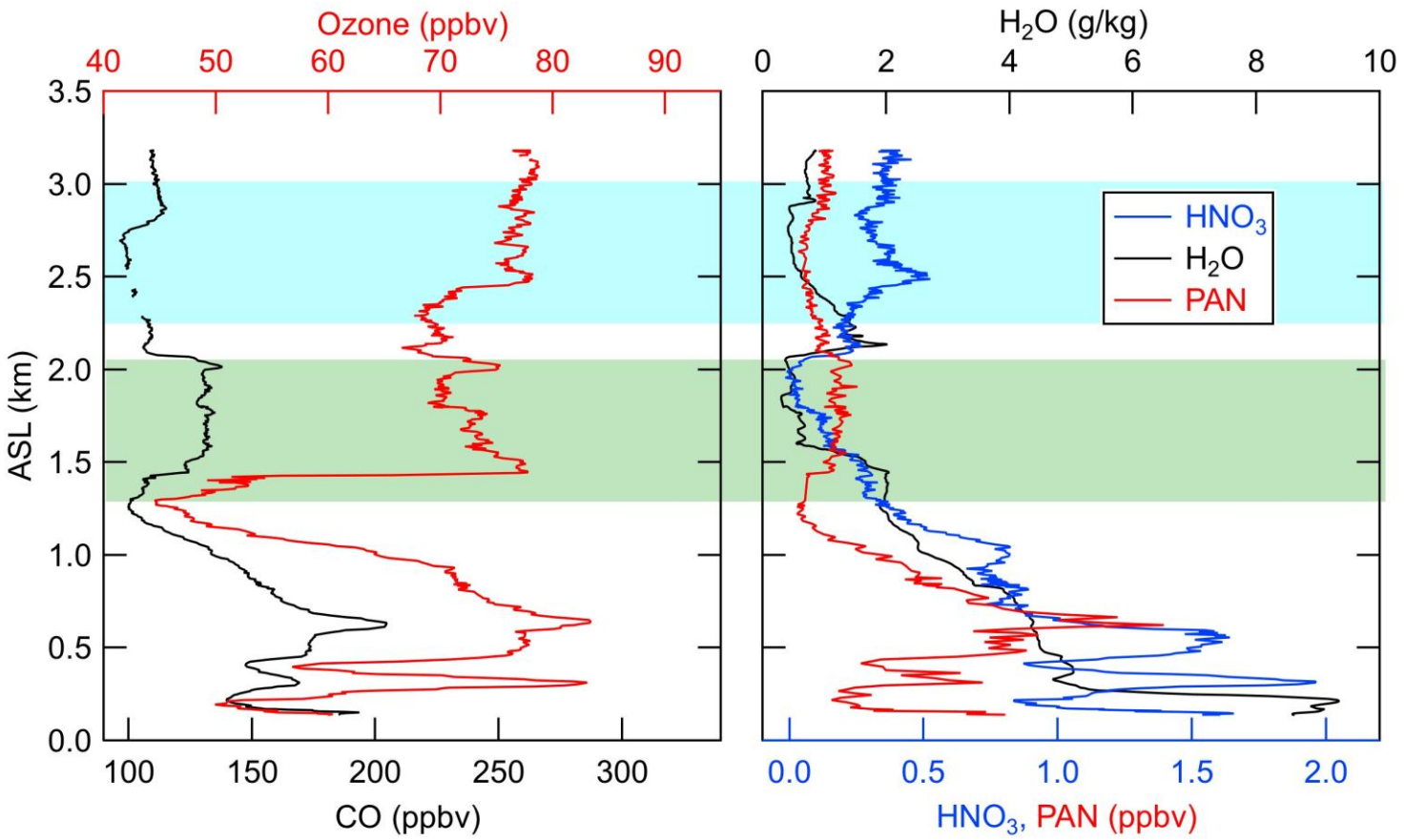
Profile in east LA Basin on May 4



- Decreased CO, water, HNO_3
- Increased Ozone from Upper Tropospheric influence

Ozone in the lower free troposphere over the LA Basin

Profile near Catalina Island on May 8



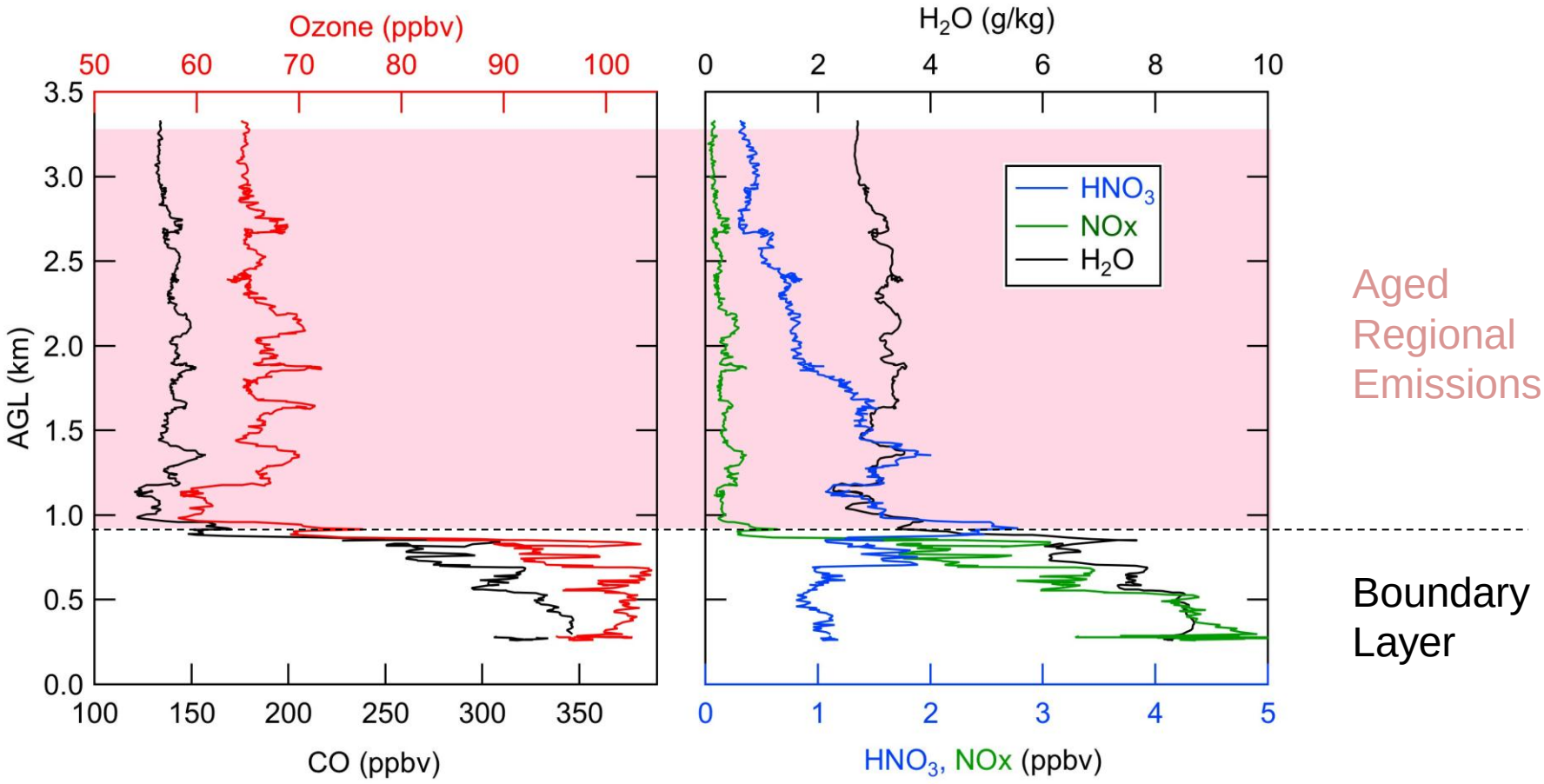
Upper Tropospheric

Long Range Transport

- Upper Troposphere: decreased CO, water, HNO_3
- Long Range Transport: decreased water, HNO_3; increased CO and PAN
- Increased Ozone from Upper Troposphere and Long Range Transport

Ozone in the lower free troposphere over the LA Basin

Profile over Redlands on May 16



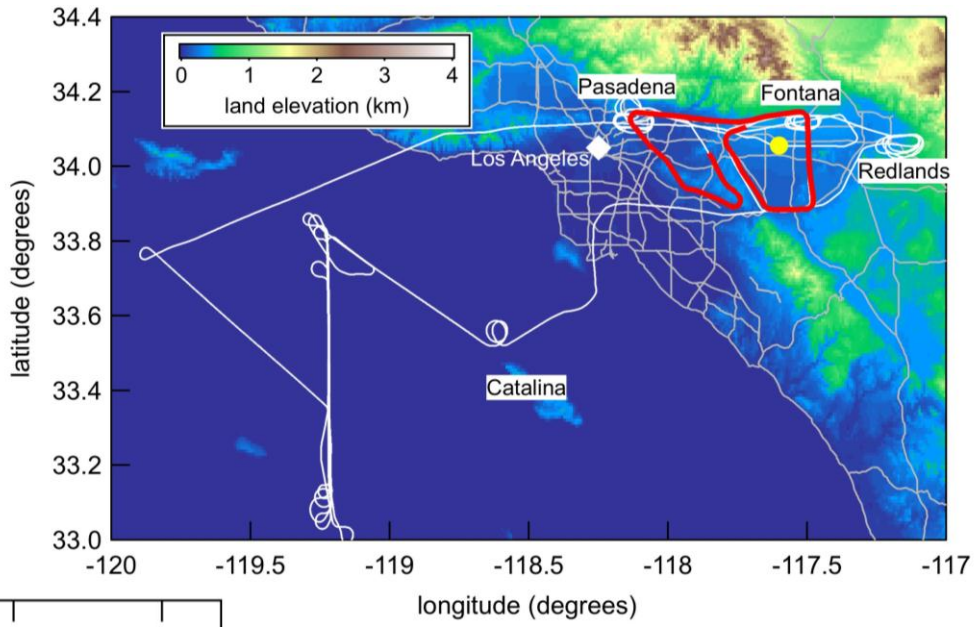
- Increased CO, water, HNO_3
- Increased Ozone from Aged Regional Emissions

Summary of 32 vertical profiles

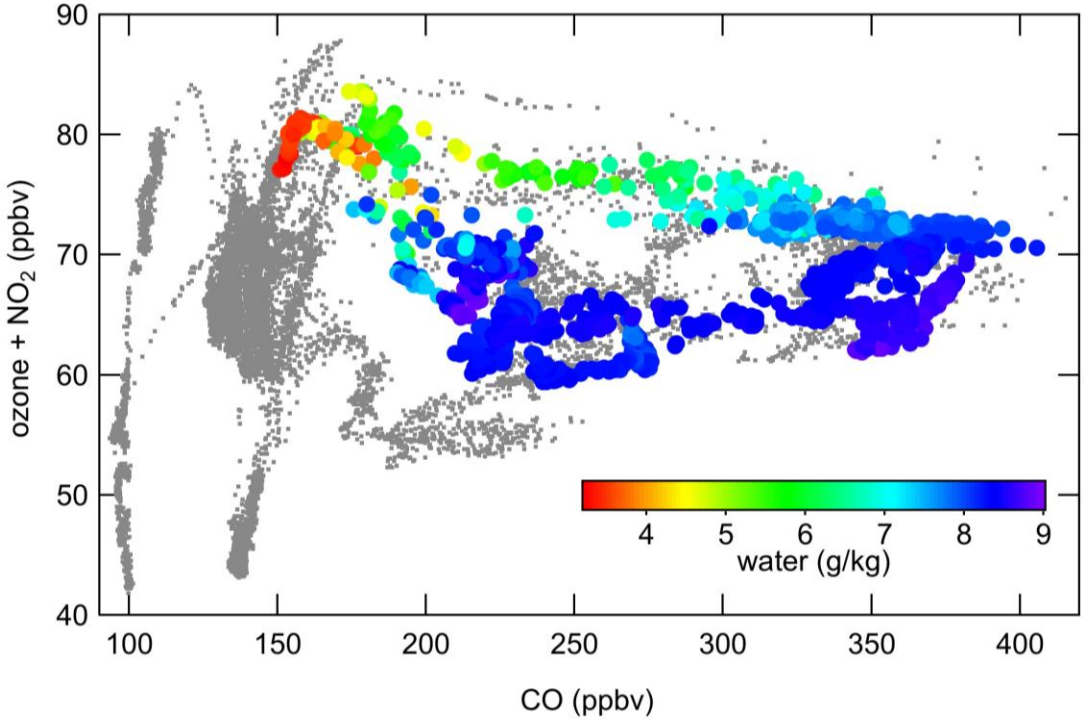
Averages from 1.8 – 3.5 km altitude

Primary Air Mass Influence	Ozone (ppbv)	CO (ppbv)	HNO_3 (ppbv)	Water (g/kg)	Fraction of observations
Upper Tropospheric	72 ± 8	108	0.41	0.75	40%
Aged Regional Emissions	65 ± 5	130	0.81	2.9	42%
Long Range Transport	71 ± 4	137	0.11	0.98	13%
Marine	51 ± 7	98	0.65	3.4	5%
Stratospheric	Not observed below 4 km over LA Basin on 6 WP-3 flights				

Example: Downward mixing of ozone into LA Basin, May 14



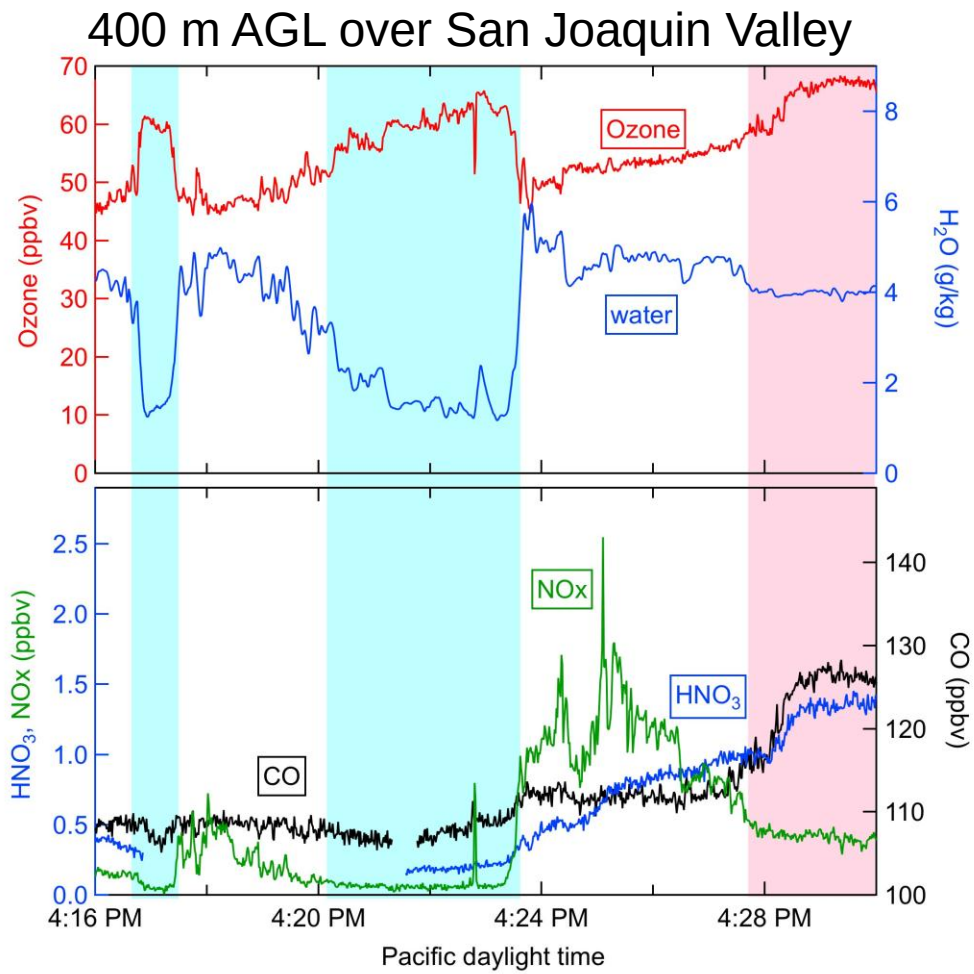
Ozone:CO correlation

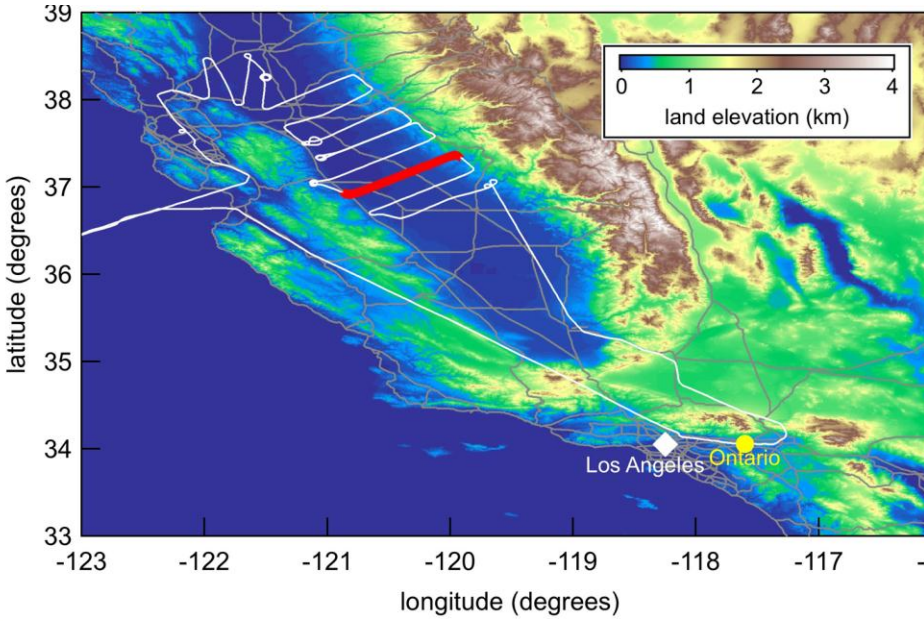


- Gray points: Entire flight
- Colored points:
  0.2 – 0.8 km altitude over East LA basin

- Dry air with increased ozone and low CO mixed into LA Basin

Example: Downward mixing of ozone into central valley, June 18





- Decreased CO, water, HNO_3: Ozone from aloft mixed to surface
- Increased CO, HNO_3 Ozone from aged regional emissions

Upper Tropospheric Influence

Aged Regional Emissions

Implications

1. Ozone from upper troposphere an important source over the LA Basin.

2. Downward mixing of ozone may have same temporal and spatial pattern as photochemical production.

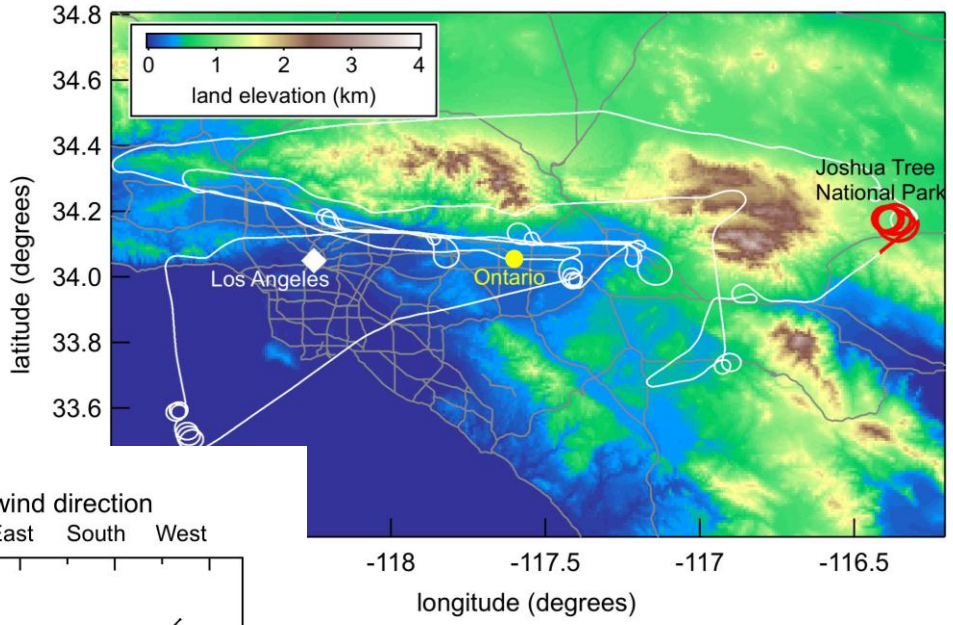
3. Entrainment of ozone from aloft affects correlations between ozone and tracers.

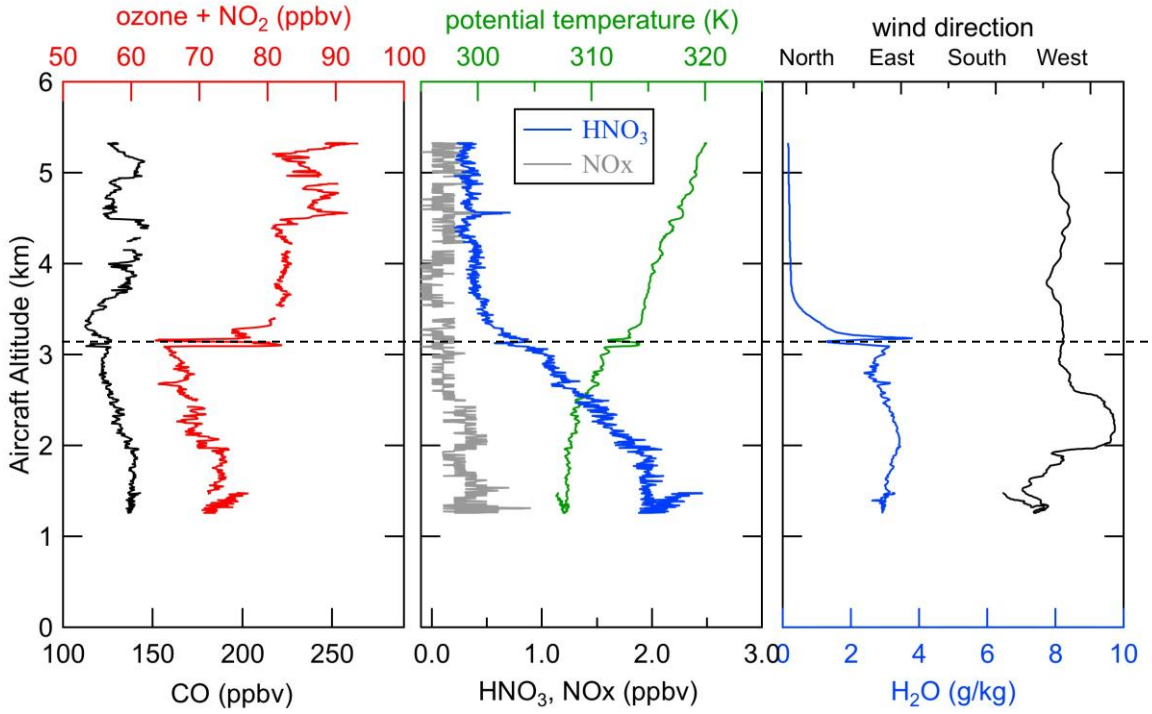
4. Ozone boundary condition at top of boundary layer is dynamic. Average values don't reveal the conditions most important to exceedances.

5. Downward mixing of ozone aloft especially important over high desert (deep boundary layers).

6. Upper tropospheric influence seen in previous years, and could be monitored from commercial aircraft; Measurements of OZone, water vapour, carbon monoxide and nitrogen oxides by in-service AIrbus airCraft (MOZAIC) or In-service Aircraft for a Global Observing System (IAGOS).

Example: Increased ozone Joshua Tree National Park May 4

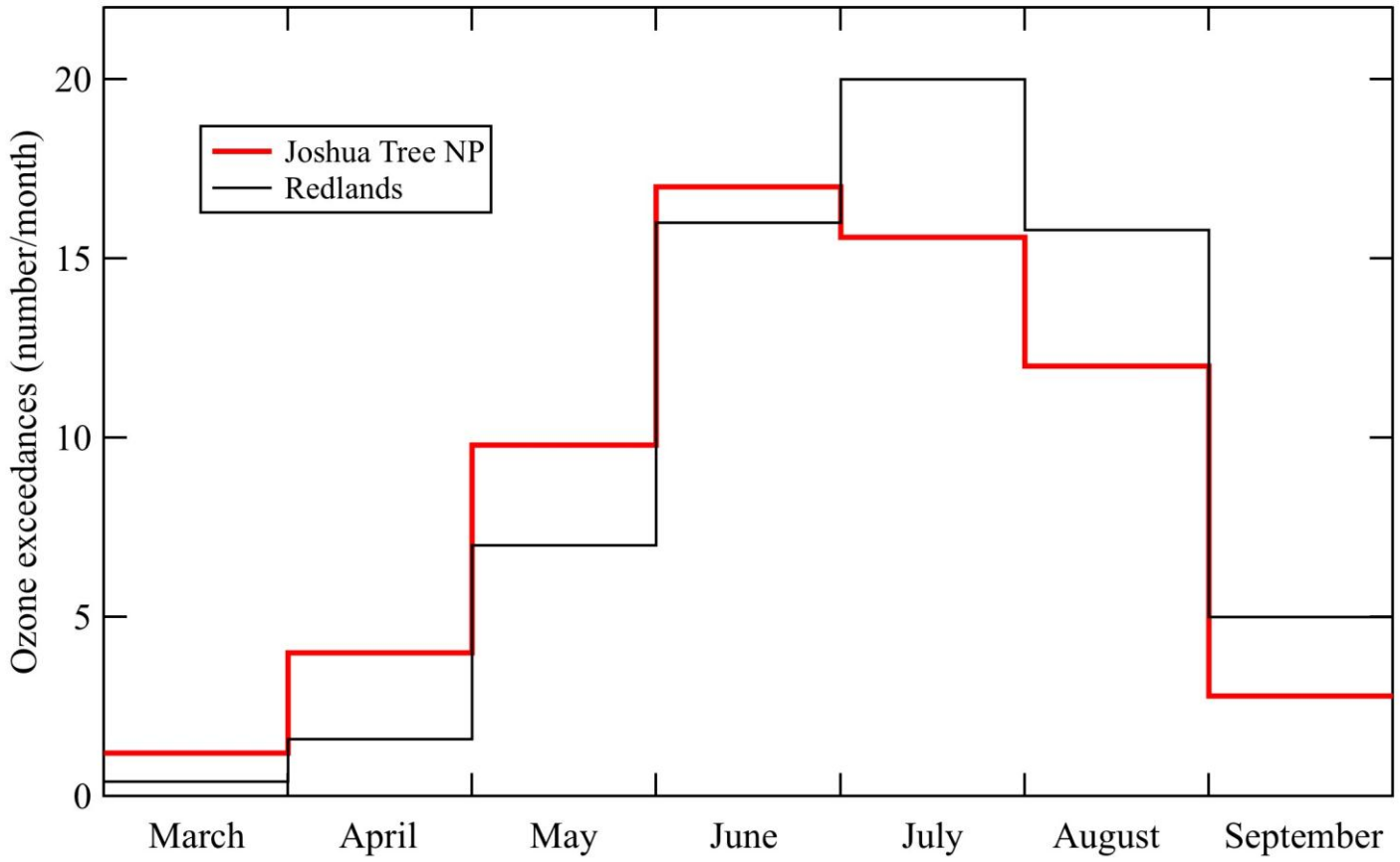




Boundary Layer

- Decreased HNO_3, water aloft. CO variable.
  Long Range Transport or Upper Troposphere
- Over high desert, deep mixing layers entrain ozone aloft

Daily exceedances of 75 ppbv daily 8-hr average ozone at Joshua Tree National Park and Redlands, averaged from 2006-2010



Joshua Tree has more exceedances in the spring

MOZAIC (Measurements of OZone, water vapour , carbon monoxide and nitrogen oxides by in-service AIrbus airCraft

May 12, 2005, in and out of LAX